Fallout Dosage and Monitoring

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• At present there are a large number of people capable of conducting the task of surface and area radiation monitoring including external monitoring of personnel. Once the extent and the intensity of radioactivity in an area is determined, good use of personnel can be made without too much risk. This is fortunate for the medical profession whose personnel can devote their talents to casualty care during or following nuclear warfare. Most individuals who know how to detect and measure the extent of radioactive contamination are also capable of conducting personnel decontamination operations and would do so if necessary. Consequently the spread of contamination can be minimized by adequate decontamination and the medical personnel can treat casualties who are relatively free of external radioactive contamination. The appropriate use of trained manpower and radiation detection equipment which are available in California combined with sufficient rehearsals prior to a nuclear war will greatly reduce any casualty damage due to radioactive fallout.

The chances of survival of individuals can be greatly improved with a little knowledge of protection from radioactive contamination and of salvage of food and water.

THE RADIOLOGICAL CONTAMINANTS from the atom bomb are fission products. The hydrogen bomb utilizes the energy from the fission reactions to start a thermonuclear or fusion process which produces helium from hydrogen and likewise releases energy. Since the helium (He^4) is not radioactive, and is a gas, the increase in fallout activity produced by a thermonuclear weapon must come from the fission of the uranium or plutonium that is used as a fuel.

An estimate of the amount of material composing the fission products can be obtained from the data on ordinary A-bombs, namely, that for each 20,000-ton TNT equivalent rating about two pounds of radioactive material is produced in the fission process.[5] A 15-megaton bomb would produce some 1,500 pounds of radioactive material.

FALLOUT

The energy released in an explosion of a nuclear weapon is sufficient to vaporize and heat to incan-

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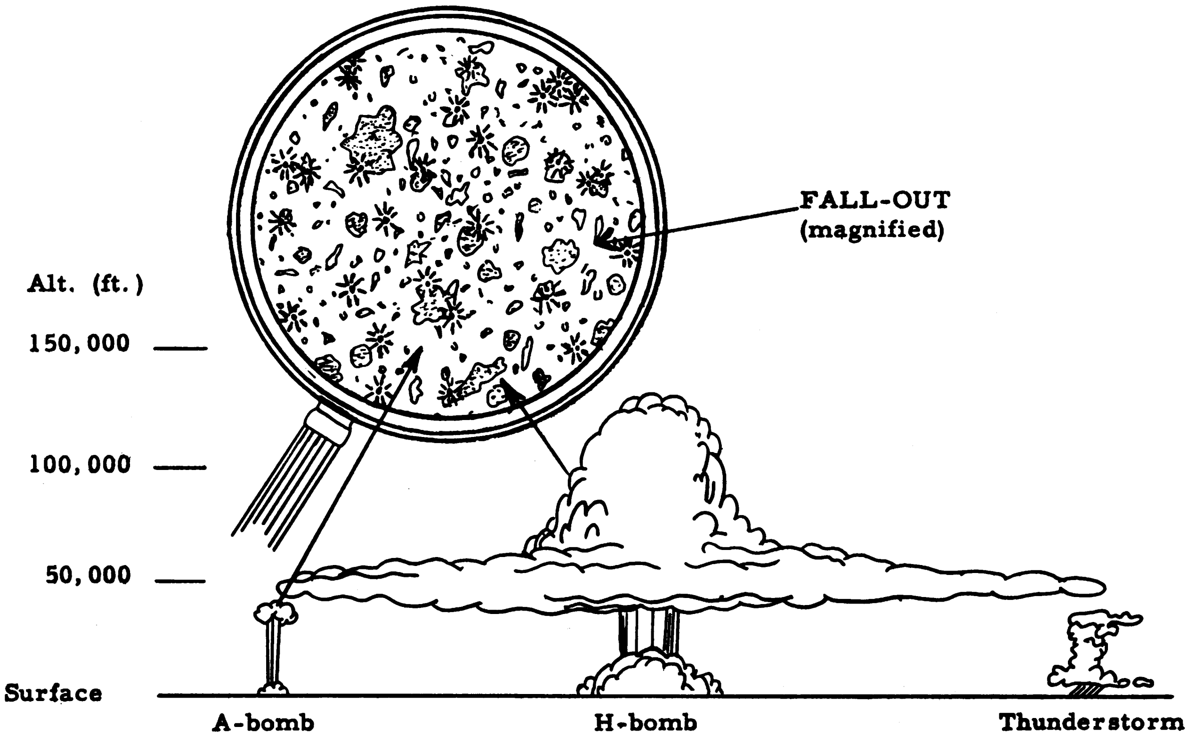


Comparative size of A-bomb mushroom, H-bomb mushroom and ordinary thunderstorm cloud.

descence all the fuel (uranium, plutonium and hydrogen bearing material), the fission products, the bomb casing and components, and the radioactive materials produced by neutron bombardment of the medium surrounding the bomb at the time of detonation. This incandescent mass, called the fireball, starts skyward shortly after it is formed, and at the same time becomes diluted with air, dust and dirt from the ground and the space between the ground and point of detonation. The fireball then appears as the frequently described mushroom-shaped atomic cloud, the internal portion of which is still extremely hot, but cooling as it ascends. When the vaporized components of the cloud cool sufficiently they will condense or solidify. This process generally takes place on the unvaporized material such as the dusts which were sucked into the cloud during its ascent. The solid particles, whether they are radioactive or not, will begin to descend as soon as they are swept out of the rapidly rising cloud by the cross winds at various altitudes and as soon as the mushroom-shaped cloud has reached its ultimate height. The precipitation or settling of these radioactive particles is known as fallout. The extent and nature of this fallout will be determined by such factors as altitude of the burst, the height to which the cloud rises, type of medium in which the bomb was detonated (air, liquid or solid) and the meteorological conditions as illustrated on next page.[2]

It is generally stated that the fallout from an air burst constitutes little or no radiological hazard, that the hazard from a subsurface explosion would probably not spread far from ground zero, but the fallout from a surface burst might be dangerous even at some distance from the explosion. Since the fireball produced in the detonation of a hydrogen bomb is several miles in diameter, it is likely that the explosion would be a contaminating burst. In addition the radioactivity released in a nuclear weapon is in proportion to the energy released, and these weapons are now considered to have TNT equivalents of millions of tons (megatons). Consequently the fallout from a surface burst of a weapon of this type would constitute a serious hazard in an area of 7,000 or more square miles.

In estimating and predicting the area affected by fallout, it is necessary to have good meteorological data and to utilize personnel with training and proficiency in meteorology to plot the data and evaluate the results. Two factors that are always considered in calculating the fallout areas are the size of particles formed and the prevailing winds. The large dust particles settle rapidly and are affected for the shortest time by the prevailing winds. The smaller dust particles settle slowly and are spread to greater distances.[5] An important point to remember in the estimation of fallout areas is that the surface wind plays only a small part in the distribution of these particles. Upper level winds often blow in opposite directions to those at lower altitudes.

For all critical target areas, the U. S. Weather Bureau makes twice daily forecasts of the direction of fallout drift and the probable arrival time. It is planned to expand this service to cover all areas of the country. This information provides to local, state, regional and national Civil Defense the data necessary for the construction of fallout plots. Details of the program are described in FCDA Advisory Bulletin No. 188, dated May 25, 1955, and Supplement No. 1, dated August 16, 1955. Instructions are included for constructing fallout plots from the Weather Bureau forecasts.

These fallout predictions are useful for Civil Defense planning, but limitations must be recognized. The present forecasts do not cover all of the country; they apply only to the critical target areas. Since forecasts are released only twice a day, the fallout plots sometimes will be based on wind measurements more than 12 hours old.

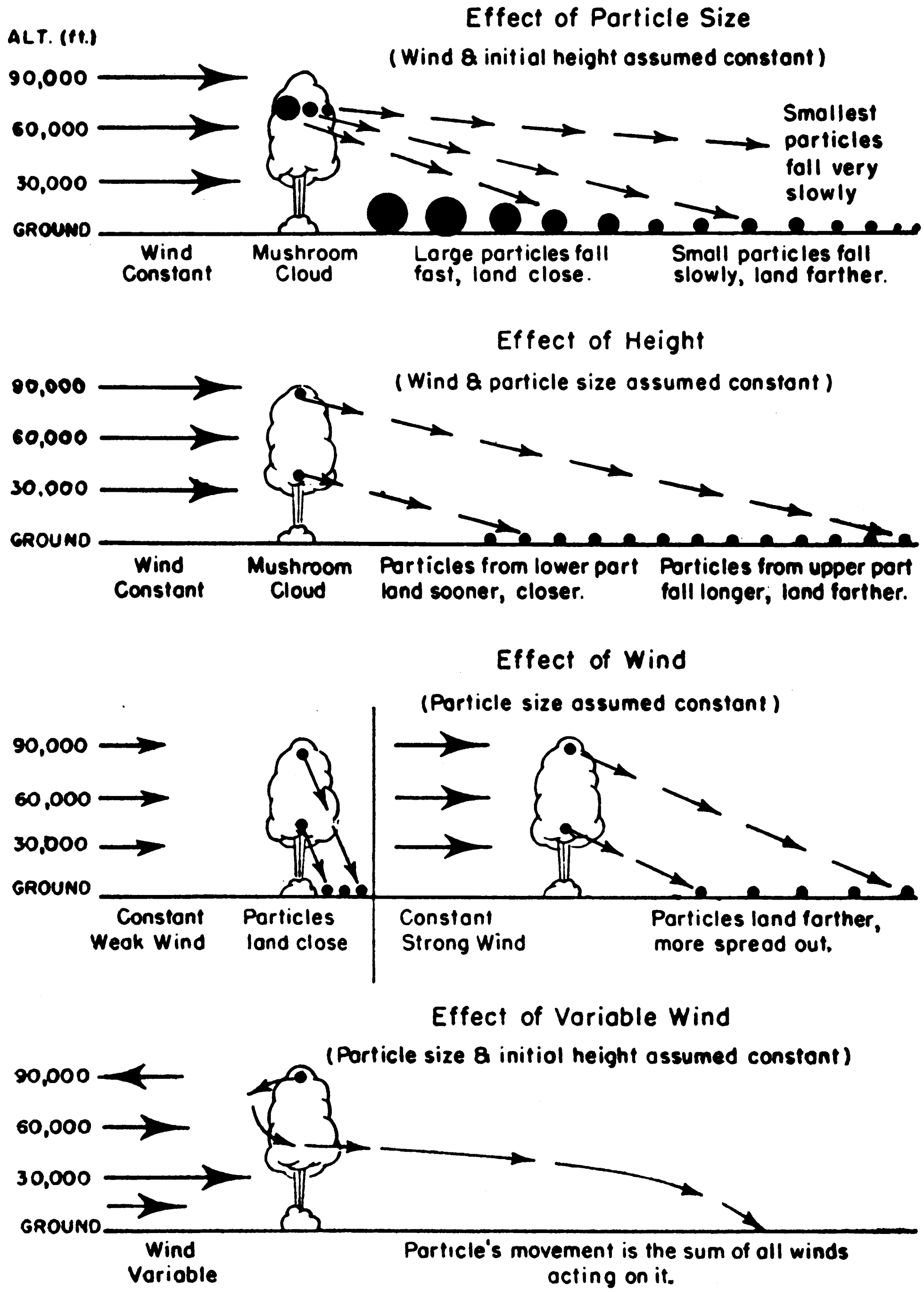
The data as released by the U. S. Weather Bureau will not be sufficient in itself to ascertain the radiation levels in the fallout areas. The H-bomb tests in the Pacific were helpful in providing some information on contamination levels for that particular detonation in that area. The following table gives an estimate of probable contamination from a 15-megaton weapon.[4]

Time (After Burst)	Contaminated Area	Average Intensity (Gamma Radiation per Hour)
1 hour	250 sq. mi.	2500 roentgen
3 hours	1200 sq. mi.	200 roentgen
6 hours	4000 sq. mi.	30 roentgen

If we ever experience fallout contamination from a nuclear weapon the accuracy of the prediction of fallout area will depend upon the accuracy of the weather data at the time and the abilities of our meteorologists. In any event, monitoring will be necessary to determine the contaminated area and the amount of radiation to which people in the area are exposed.

RADIOLOGICAL HAZARD

The half-life of the radioactive materials in the atomic cloud varies from a few seconds and minutes for some species, to hundreds of years for others. The fallout will contain many radioactive species, some of which can be an internal hazard if they are admitted to the body, and all can constitute an external hazard when outside but in the vicinity of the body. With such a wide variety of contaminants present in different amounts and each decaying at



Factors affecting distribution of radioactive particles.

its own rate, the task of obtaining the desired information on the amount of radiation which a person might receive if he were required to work in the fallout area appears a difficult one. There is, however, an empirical relation between (1) the intensity of radiation in the fallout, (2) the time interval between radiation measurements and, (3) the average decay constant for fission products. This empirical relationship is an exponential or logarithmic one and all expressions of time must be in terms of the same unit, generally in hours.

The relationship between the total body cumulative dose, the intensity of radiation an hour after the explosion (H + 1) and the length of time of exposure also involves a logarithmic solution. Both of the above empirical relationships are incorporated in the nomograph shown on the following page, which can be used as follows:

(1) To obtain the activity or intensity of radiation at any given time, utilize:

(a) A radiation detection instrument to measure the activity or intensity of radiation from the contaminating fission products (fallout) at a known time after the detonation or blast, and

(b) Columns A, B and D of the nomogram.

(2) The dose for the first hour after the blast is approximately 2.5 times the dose accumulated between H + 1 and H + 2 hours. By using columns B, C and F of the nomogram, the cumulative dose from H + 1 to any other time may be obtained.

(3) The infinity dose (dose for a long or infinite time) is the accumulated dose received by exposure to the effective life of all the fission products, and may be calculated from any desired time after the fallout has occurred by using columns B, C and E as illustrated in the following examples:

PROBLEM	SOLUTION
1. The radiation level in a contaminated area has been measured to be 500 milliroentgens per hour (mr/hr) 8 hours after an explosion of an atom bomb. What was the radiation level 1 hour after the explosion?	Place a straightedge connecting 500 mr/hr on column D with 8 hours on column A. Read from the point at which the straightedge crosses column B (6,000 mr/hr).
2. What is the cumulative radiation dose in a contaminated area between H + 1 and H + 8?	Connect 6,000 mr/hr on scale B with 8 hours on scale F. Read from column C, a cumulative exposure of 10,000 mr (10r).
3. What will be the infinity dose in the area following H + 8 hours?	Connect 6,000 mr/hr on scale B with 8 hours on scale E. Read from C, an infinity dose of 20,000 mr (20r).
4. What dose will personnel accumulate who are in the contaminated area between H + 2 and H + 8? Solution of problems of this type require the subtraction of two cumulative dose computations.	Cumulative dose from H + 1 to H + 8 has previously been computed to be 10r. To determine the dose between H + 1 and H + 2, place a straightedge to connect 6,000 mr/hr on scale B, with 2 hours on scale F. Read 4,000 mr (4r) from scale C. The dose from H + 2 to H + 8 is the difference between these two determinations: 10r — 4r = 6r.

MONITORING

As a basis for measures to protect personnel remaining in or likely to enter an area after nuclear detonation, the degree and extent of radiological contamination must be determined. A few haphazard instrument readings will not suffice; a systematic survey is necessary. In general, there are two steps that should be included:

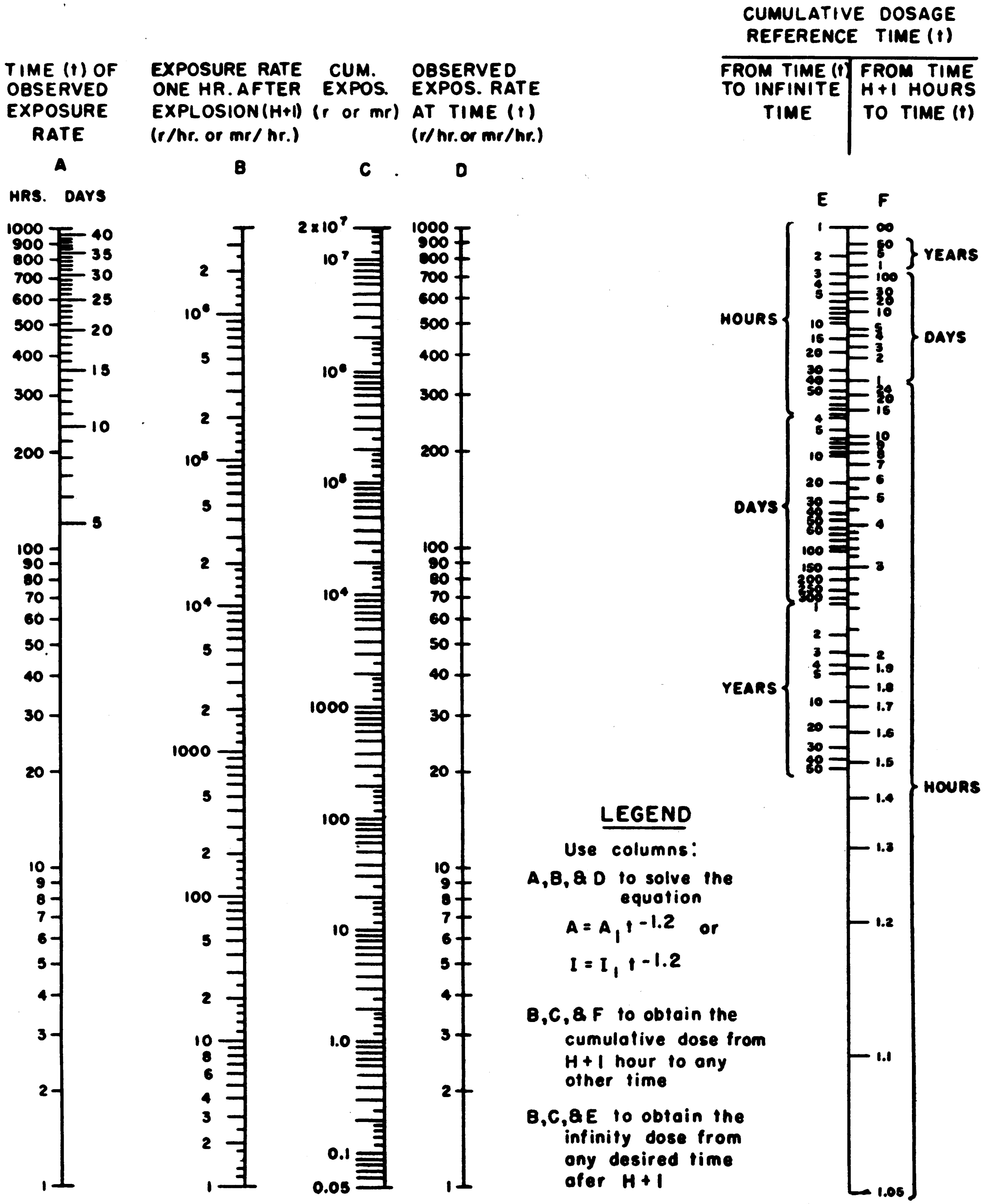
1. The first step, concerned with the gross contamination, is a rapid survey to determine the immediate safety precautions and necessary rescue operations. This survey applies to either land or sea areas and should be made by air monitors and followed by surface monitors. It is apparent, however, that in order to obtain enough data quickly, it will be necessary to have a number of trained monitors to take measurements of radioactivity throughout the area suspected of contamination. These monitors may be anyone designated by the Civil Defense chief in the area. They must be well trained in the use of instruments and in making accurate reports of the observed data. A monitor should also know how to interpret the results of his findings to a degree sufficient to be responsible for his own immediate safety and that of others near him in case he should find himself in a region of great radiological hazard. The instruments to be used by such monitors have been specified by OCDM. However, other portable beta-gamma radiation detecting instruments may be used, if they are available for such operations.

Monitors should be assigned to each unit area on the basis of a previously designated grid system. Following radiological attack, each monitor should proceed to his assigned area and conduct his survey with a high-intensity survey meter, taking frequent readings, until he reaches an area in which radioactivity is above the tolerance level as previously established by the defense organization. He should report his findings to the proper authority promptly and frequently by whatever means of communication is available, preferably two-way radio. If the monitor finds that he is already in an area above tolerance, he should evacuate to an area of lesser activity, warning others to do likewise. If he finds that his entire area is below tolerance, he must stand by within his area and continue monitoring and reporting, unless ordered otherwise.

2. The second step should be a detailed and accurate survey over a considerable time to obtain information on the exact nature, extent and rate of decay of the radioactivity present. This survey may include analyses of contaminated samples by state department or university laboratories and should lead to a prediction of the probable degree of hazard remaining in the area at any specified future time. Such information is vital in determining the extent to which evacuation, decontamination and reentry into the area should be effected.

Assuming that the rapid survey within any given unit area has been completed and that the monitor is still within his area or that he has reentered an area where the intensity has decayed sufficiently to permit at least short-duration operations, the monitor will proceed with the detail survey. This time he may use a more sensitive or lower-intensity survey meter, such as a G-M type, taking readings at more locations and with greater regularity. It is important that he continue to report his results to the proper authority or to the damage control center. If there should be no radiation evidenced except normal background count within the area under survey, monitors must nevertheless make continued

GAMMA RADIATION DOSAGE FROM FISSION PRODUCTS



A = Radioactivity at arbitrary time. A_1 = Radioactivity at any stated time thereafter.
I = Intensity of radiation at arbitrary time. I_1 = Intensity at any stated time thereafter.
t = time interval between A and A_1 or I and I_1. H = Explosion of bomb.

surveys of their entire areas if these lie within the region of possible fallout. This is necessary to detect any later increase of intensity and thereby warn of approaching fallout and possible hazard. Indications of the absence, as well as of the presence, of radioactive contamination are important to the Civil Defense officer who is plotting the overall situation.

During this detailed survey, the monitor should select samples of earth, water, or small exposed objects and transmit them through his Civil Defense Central Office to a radiological laboratory where they may be checked for radioactivity. Laboratory analysis should also lead to certain conclusions as to the types of materials constituting the contamination. This information would prove useful in selecting suitable decontamination procedures to be employed and, together with carefully recorded intensity readings taken at regular intervals at a few points specified by the defense officer, will form the basis for calculating the time that must elapse before a radiologically hazardous area becomes safe for occupation.

In summarizing survey operations, it cannot be too strongly emphasized that the rapid, yet accurate, reporting, recording and charting of data obtained are vital necessities if correct conclusions are to be drawn by the Civil Defense officer. Upon these conclusions, the commanding officer must base his decisions for such subsequent action as rescue, evacuation, decontamination and rehabilitation. It should also be remembered that monitors and other personnel required to work in possibly hazardous areas should be provided with suitable protective clothing and equipment and with dosimeters to provide a record of the cumulative dosage received by any one individual. This record should be used as a basis for shifting personnel to duties in less hazardous areas when they have been overexposed or appear to be in immediate danger of accumulating too great a total exposure to radiation.

In estimating the probable decrease of the radiation hazard with time, the decay rate of the ashes of the nuclear weapon can be approximated by considering that for every seven-fold increase in the age of fission products, there will be a ten-fold reduction in the radioactivity or intensity of radiation as illustrated below:

Contamination in Curies of Radioactive Material	Time After Formation of Fission Produc's	Radiation Intensity from Fission Products (Roentgens per Hour)
1,000	1 hour	10,000
100	7 hours	1,000
10	49 hours (2 days)	100
1	14 days (2 weeks)	10
0.1	14 weeks (3 months)	1

Any area that is still dangerous three months after the detonation will remain so for a long time. Unlike airbursts, surface and subsurface bursts present a hazard to all persons entering the area for some time after the explosion. The degree of the hazard will depend on the time elapsed before reentry. The civil radiological defense officer must solve this problem, either through the use of a plot, by the multiple-decay equation, by special sliderules, or by nomograms (page 76).

Some kind of radiological survey is desirable regardless of the type of burst. A natural rainfall within an hour after the burst could greatly affect the area in which it fell. Raindrops passing through the contaminated air might carry down a significant amount of contamination. Lung protection must also be considered if it is intended to operate in a contaminated area while radioactive dust might still be suspended in the air the monitors breathe.

SALVAGE OF FOOD AND WATER

It should be borne in mind that radiation is more easily dealt with when it is outside than it is when within the body. Decontamination of the skin is far easier than decontamination of the lungs, liver or bones.

All food in the damaged area may be dangerous. The food may contain some induced radioactivity, but probably not in hazardous amounts. The largest source of contamination is fallout. Radioactive dusts may be deposited on the food and water left uncovered. The following are good rules of precaution:

Isolate all unpackaged foods that were lying where dust from ground bursts or mist from underwater bursts might have settled on them. Before opening canned or bottled goods, wash the outside of the containers thoroughly. That will remove most of the pollution that may have deposited on them. Also, be sure that all cooking utensils and tableware are scrubbed clean in order to remove any invisible, radioactive dusts. Food and utensils that were in closed drawers or tight cupboards which prevented the access of fallout will be all right.

Be careful of drinking water after atomic explosions. There is little or no chance that water actually inside household pipes at the time of attack will be made radioactive. If a little is drawn off right after the burst and placed in clean containers with covers, it should tide you over the immediate postraid period.

But even if the water continues running, don't keep on using tap water for drinking purposes unless you have received official information that the city system is safe. This is not only because of radioactivity, but because of other dangers like typhoid that can come from damaged water systems. If you have to use city water before you get official infor-

Supportable Risks of Beta-Gamma Activity in Water

Period Over Which Water Is to Be Consumed	Preferable Risk		Acceptable Risk	
	Curies per Cubic Cm.	Disintegrations per Min. per Cc.	Curies per Cubic Cm.	Disintegrations per Min. per Cc.
10 days	3.5×10^{-9}	7.7×10^{3}	$9. \times 10^{-8}$	$2. \times 10^{5}$
One month	1.1×10^{-9}	2.6×10^{3}	$3. \times 10^{-8}$	$7. \times 10^{4}$

mation, boil it. Boiling won't remove radioactivity, but the chances that your water supply will be radioactive are pretty slim.

The figures in the table at the top of the page summarize the supportable risks for beta-gamma activity in food and water immediately following a contaminating atomic explosion.[1]

These levels of contamination are detectable with ordinary beta-gamma survey instruments.

GENERAL INFORMATION[3]

All radiation is damaging and should be avoided wherever possible. In cases of disaster, radiation tolerances will be changed from peacetime to emergency tolerances; and the amount of exposure to radiation will have to be weighed against the benefits to be gained. If, however, the rules, regulations and directions which have been published by your Civil Defense organizations and those being sent out by radio during the disaster are complied with, the chances of survival will be greatly increased.

Alpha, beta and gamma radiation will not cause your foods, the water or yourself to become radioactive when you are exposed to them. Neutron type radiation may induce some radioactivity; however, everything within the neutron range will probably be damaged beyond repair and should be forgone.

The handling of people or objects that are contaminated with radioactive materials should be no different than handling of people or objects that are contaminated with any kind of dust that would be detrimental if taken into your system. You will not become radioactive if you handle people who have been killed or damaged by radiation. Decontamination is a modern word for scrubbing with soap and water. However, since they cannot be destroyed, radioactive material that is washed off the walls of buildings or off people should be disposed of in such a way that they can never find their way into the human system.

Water from deep wells which are covered and undamaged will be safe to drink, provided, of course, it was satisfactory before the disaster. If the water supply is contaminated in the watershed area but the water trickles through several feet of sand and dirt before going to your water purification plant, most of the radioactive materials will be removed. Household water softeners are also efficient in removing radioactive materials from water.

In regard to shelter and shielding from radiation resulting from the radioactivity in the fallout area, as long as we can prevent internal contamination we only need to consider the gamma radiation.

CONCLUSION

Radiological defense is one part of a comprehensive integrated defense system and requires a host of technical personnel for its success. In order to properly integrate it with the other phases of the defense planning, training, and mutual aid between individuals, communities, states and countries cannot be overemphasized. The survival of each individual depends a lot on how he conducts himself before, during, and after a disaster. Training is like an insurance policy in this respect, and the premiums should always be paid for ahead of time. We cannot take the risk of allowing our training program to lapse.

Department of Health, Education and Welfare, U.S.P.H.S., Room 447, Federal Office Building, San Francisco 2.

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